İSTANBUL TECHNICAL UNIVERSITY

FACULTY OF MINES

DEPARTMENT OF GEOPHYSICAL ENGINEERING

SEISMIC MODELLING AND AVA ANALYSIS OF HIDROCARBON TRAPS

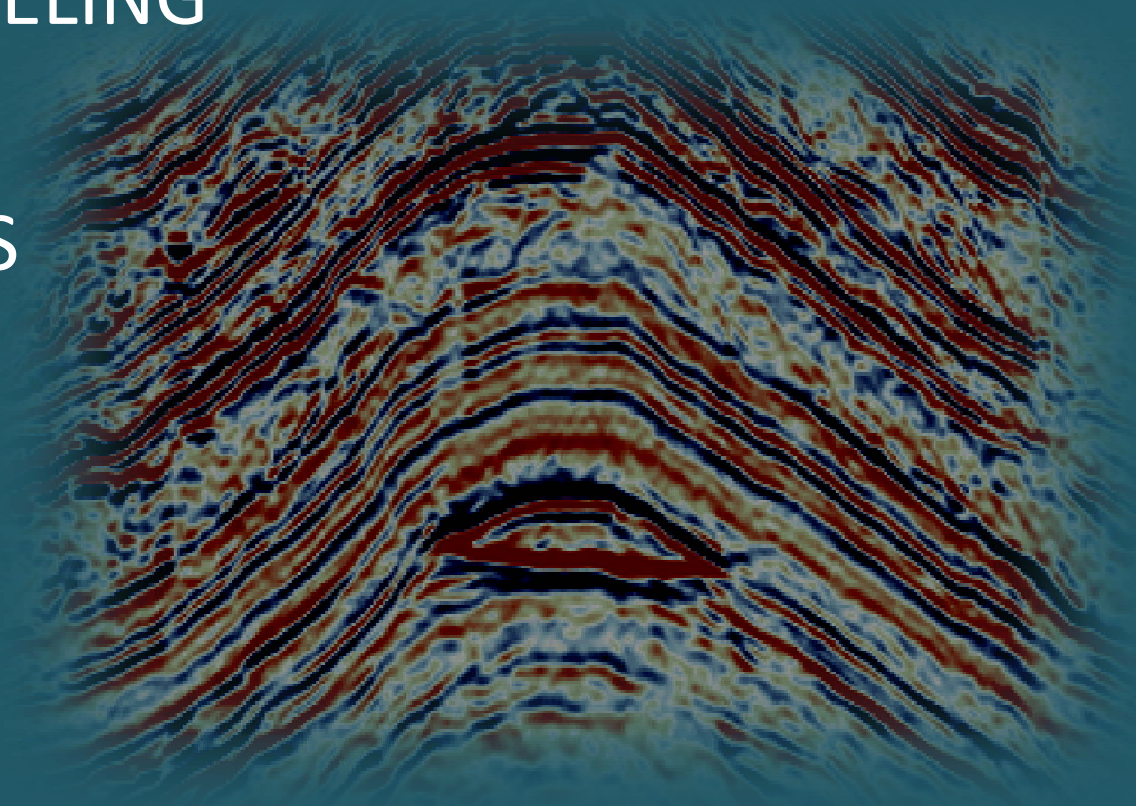
Prepared By
RICARDO J. FARO GÓMEZ
990102702

Advisor
Assist. Prof. Dr. NESLİHAN OCAKOĞLU

İSTANBUL, MAY 2011

INDEX

- INTRODUCTION
- SEISMIC MODELING
- AVA ANALYSIS
- CONCLUSIONS
- REFERENCES



INTRODUCTION

In this study, forward seismic modeling was performed for four geological models with reservoirs of hydrocarbons (HC´s).

There are two kinds of HC traps.

-Structurals.

-Stratigraphics.

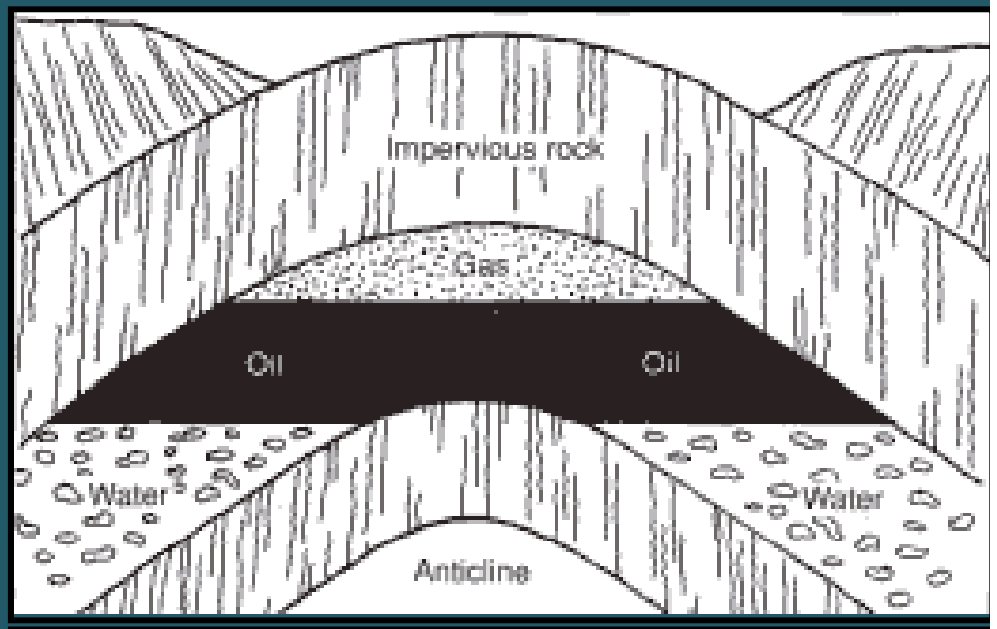
The seismic response of the contact with HC´s is called HC indicator.

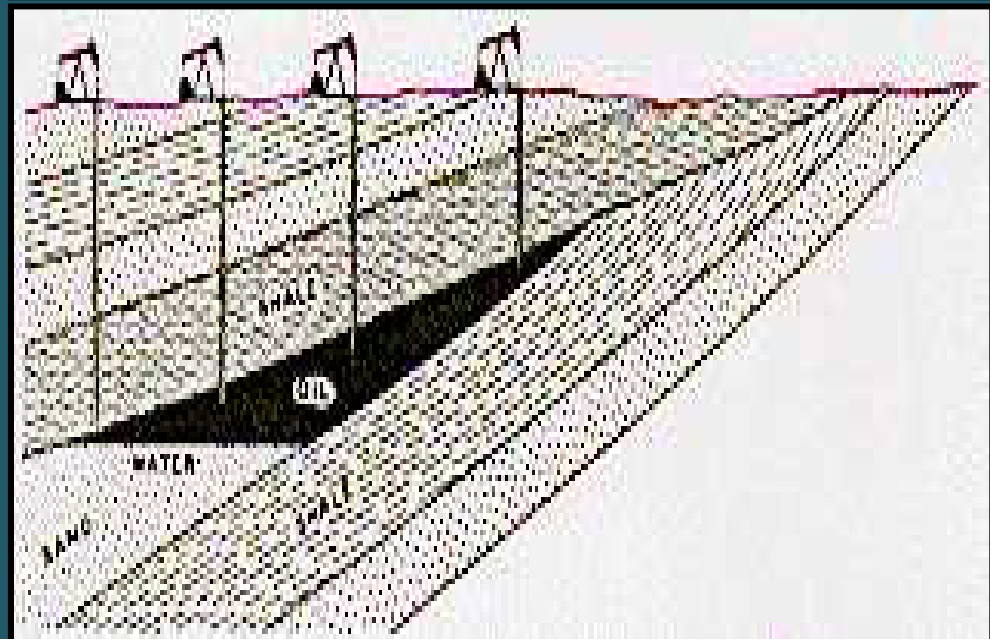
-bright spot.

-BSR.

-flat spot.

-dim spot.

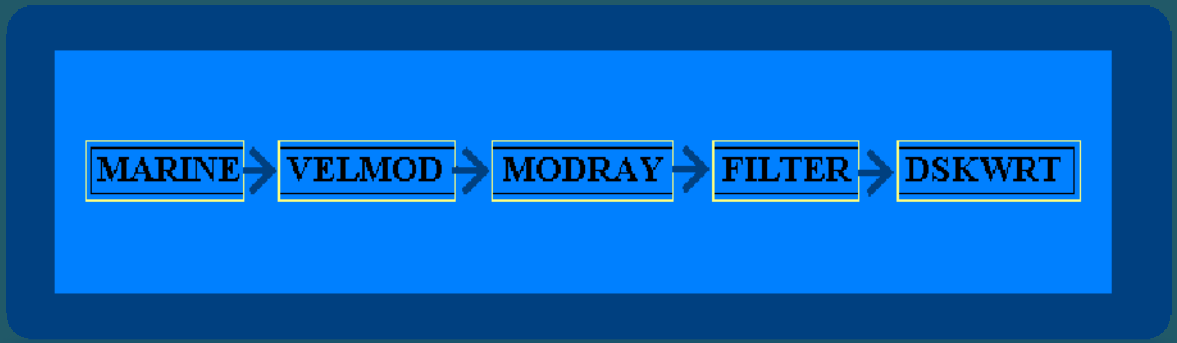




SEISMIC MODELING

The seismic modeling was performed with DISCO/FOCUS program version 5.0 under Linux/Unix operating system

Parameters should be introduced by DISCO modules



MARINE generates the geometry of a conventional marine line.

VELMOD defines the geological models with the velocity and depth of each layer.

MODRAY performes the ray tracing modeling to create the seismic response.

FILTER designes time and spatially varying filters and applies them to seismic data.

DSKWRT writes seismic traces and their headers and stores them in a disk file.

```
*job    lisans  line4   neslihanlayers
*call   marine  50      48      1       20      10      20
1
*end
```

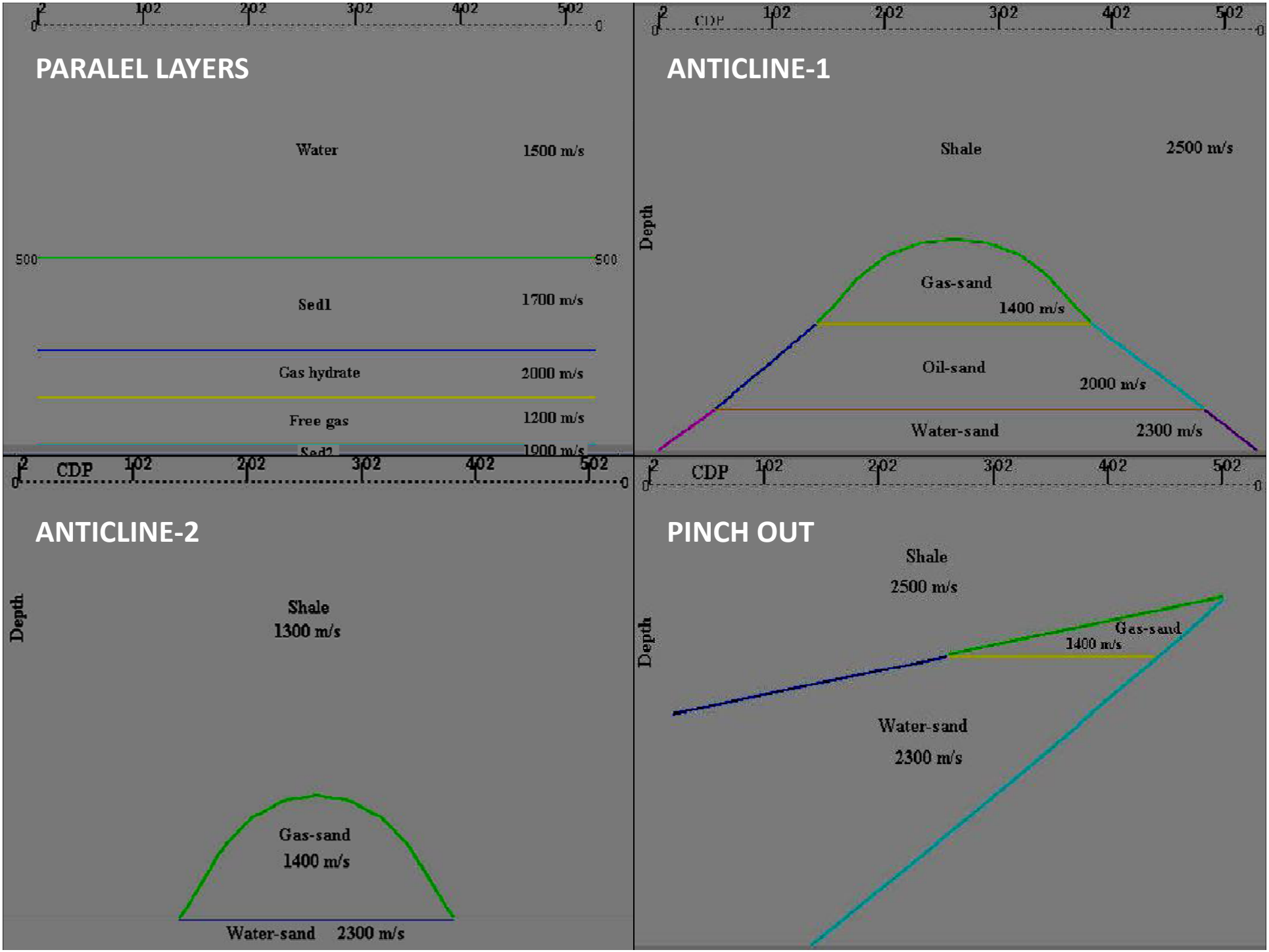
MARINE

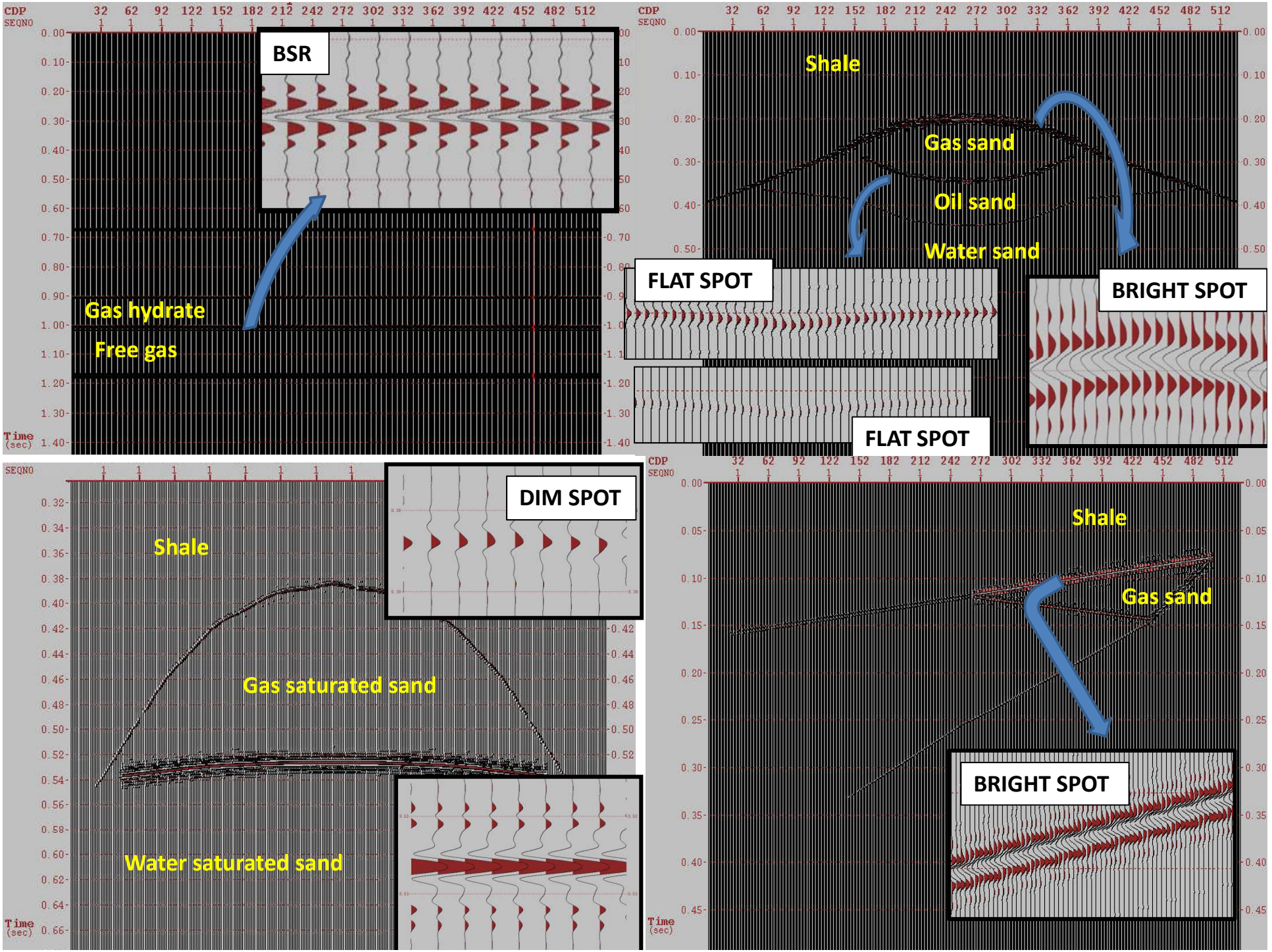
```
*job    lisans  line4   neslihan        layers
*call   velmod  layers  cdp
horizon surface
2       0       1500    0
528     0       1500    0
horizon hor1
2       500     1700    0
528     500     1700    0
horizon hor2
2       700     2000    0
528     700     2000    0
horizon hor3
2       800     1200    0
528     800     1200    0
horizon hor4
2       900     1900    0
528     900     1900    0
*end
```

VELMOD

```
*job    lisans  line4   disconeslihan   anticline
*call   modray  anticl  normal  1000    1
keydef
raypath
*call   dskwrt  /disk0/neslihan/ricardo/anticline.dsk
*call   filter  cdp                     TIME
keydef
BAND    BP
                50      150     400     450
*call   dskwrt  /disk0/neslihan/ricardo/anticlinef.dsk
*end
```

MODRAY / FILTER


PARALEL LAYERS
2
102
202
302
402
502
0
Water
1500 m/s
500
500
Sed1
1700 m/s
Gas hydrate
2000 m/s
Free gas
1200 m/s
Sed2
1900 m/s
CDP
ANTICLINE-1
Shale
2500 m/s
Depth
Gas-sand
1400 m/s
Oil-sand
2000 m/s
Water-sand
2300 m/s
ANTICLINE-2
Shale
1300 m/s
Gas-sand
1400 m/s
Water-sand
2300 m/s
PINCH OUT
Shale
2500 m/s
Gas-sand
1400 m/s
Water-sand
2300 m/s


BSR
Gas hydrate
Free gas
Shale
Gas sand
Oil sand
Water sand
FLAT SPOT
FLAT SPOT
BRIGHT SPOT
DIM SPOT
Shale
Gas saturated sand
Water saturated sand
Shale
Gas sand
BRIGHT SPOT
CDP
SEQNO
Time
(sec)

AVA ANALYSIS (Amplitude versus Angle Analysis)

It is necessary to have a complementary study focusing in the strength of the reflection amplitudes

AVA analysis examines the changes in seismic wave amplitudes with the variation of the angle of incidence of seismic wave

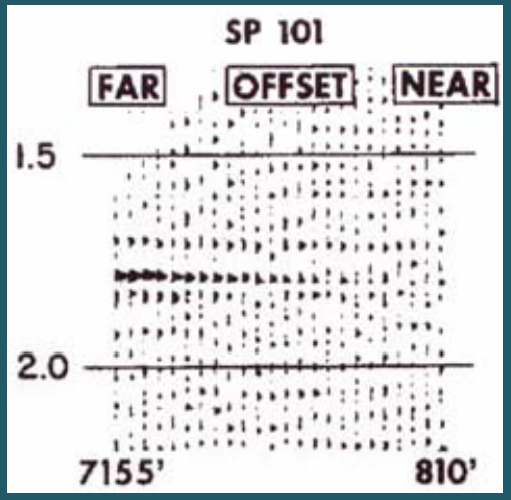
Zoeppritz equations govern the behavior of the wave dictating the determination of reflection and transmission coefficients or amplitudes for both p- and s-waves as a function of angle of incidence.

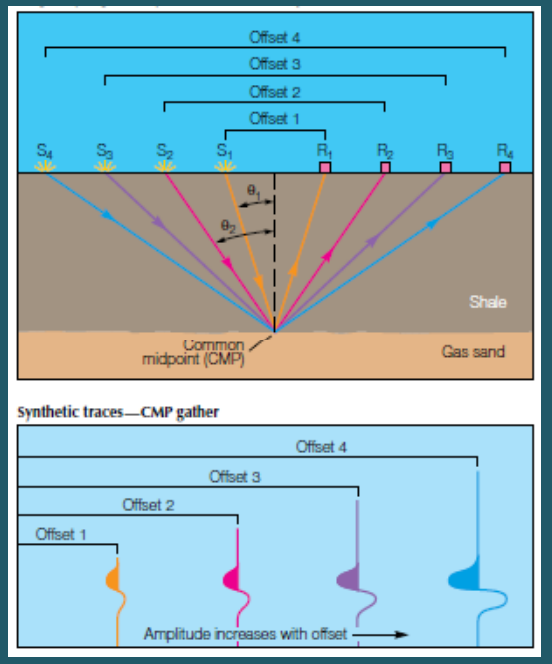
$$\begin{pmatrix} \sin\theta ip & \cos\theta Rs & -\sin\theta rp & \cos\theta rs \\ \cos\theta ip & -\sin\theta Rs & \cos\theta rp & \sin\theta rs \\ \sin 2\theta ip & a_1\cos 2\theta Rs & b_1\sin 2\theta rp & -c_1\cos 2\theta rs \\ \cos 2\theta Rs & -a_2\sin 2\theta Rs & -b_2\cos 2\phi_t & -c_2\sin 2\theta rs \end{pmatrix} \times \begin{pmatrix} R_{pp} \\ R_{ps} \\ T_{pp} \\ T_{ps} \end{pmatrix} = \begin{pmatrix} -\sin\theta ip \\ \cos\theta ip \\ \sin 2\theta ip \\ -\cos 2\theta Rs \end{pmatrix}$$

Rpp, Rps, Tpp and Tps are the reflection (R) and refraction (T) coefficients

AVA ANALYSIS (Amplitude versus Angle Analysis)

- It is needed large offset to see AVO response





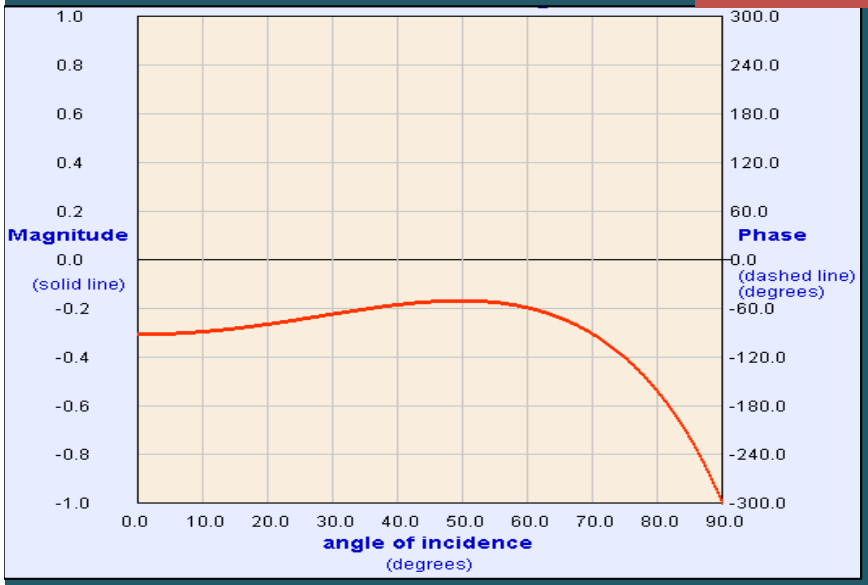
- CREWES Zoeppritz Explorer program
- Exact solution
- P-wave velocity (m/s), s-wave velocity (m/s), density (kg/m3)

- Vp = √3 * Vs
- ρ = 1,741 Vp ^0,25 (the Gardner relationship)
- Poisson´s ratio is also affected by pore fluid change

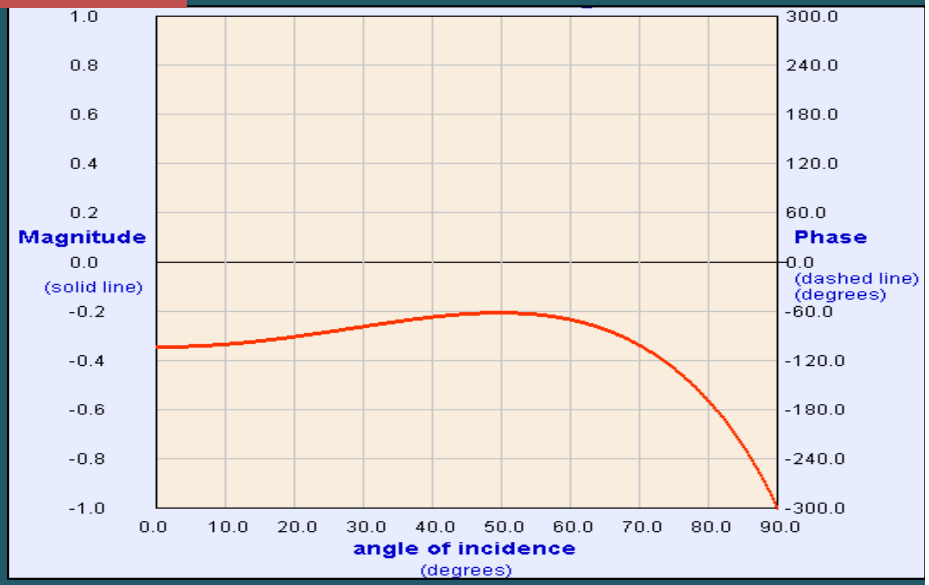
$$\sigma = ((Vp / Vs)2 - 2) / 2((Vp / Vs)2 – 1)$$

AVA curves of HC contacts in each model

Gas hydrate – Free gas (Parallel layers) BSR

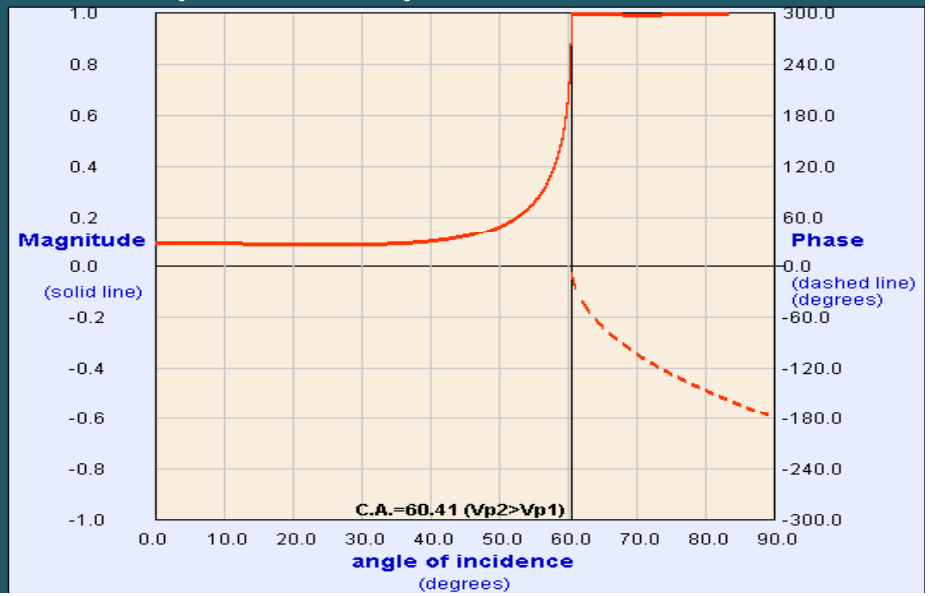


Shale – Gas sand (Anticline-1) BRIGHT SPOT



Shale – Gas sand (Anticline-2) DIM SPOT

Oil sand – Water sand (Anticline-1) FLAT SPOT



Models	Poisson ratio	Layer above	Layer bellow
Shale –Gas sand (Anticline-Contact 1)	σ	0.314	0.299
Gas hydrate -Free gas (Parallellayers–Contact 3)	σ	0.283	0.242
Gas sand –Oil sand (Anticline-Contact2)	σ	0.299	0.283
Oil sand –Water sand (Anticline-Contact3)	σ	0.283	0.312
Shale –Gas sand (Pinchout-Contact 1)	σ	0.314	0.299
Gas sand -Shale (Pinch out-Contact 2)	σ	0.299	0.314
Watersand–Shale (Pinchout-Contact 4)	σ	0.312	0.314
Freegas–Sediments2 (Parallellayers-Contact 4)	σ	0.242	0.308

CONCLUSIONS

- **Generally the seismic response is different from the real geology because of the p-wave velocity change. When the p-wave velocity is lower the wave takes longer to through the layer**
- **The most important parameter during the modeling is the P-wave velocity**
- **Generally, in the seismic response, the strongest reflections are coming from Shale – Gas (BRIGHT SPOT) and Gas hydrate – Free gas zone (BSR) with negative reflection amplitude**
- **BSR shows the bottom of the gas hydrate in the medium. If there is no gas below Gas hydrate (in parallel layers model) probably it is not possible to see BSR reflection**
- **It is possible to observe the weak signal of the Dim spot in the Anticline-2 model**
- **Generally, flat spots show liquid/liquid contacts such as oil/water, gas/water. The contact Gas – Water in the Antcline-2 is the strongest one**
- **The strongest zero offset reflection amplitude and the most amplitude change versus angle of incidence have seen in Shale – Gas sand (BRIGHT SPOT) and the Gas hydrate – Free gas (BSR) contacts**
- **When the velocity decrease, the critical angle does not occur and reflections get negative values but when velocity increases with depth, critical angle occurs and all reflections get positive amplitude values**
- **Poisson´s ratio is very sensitive to the changes of seismic velocities of the layers**
- **When the pores in the rock are filled of gas the Poisson´s ratio use to low anomalously**

REFERENCES

- **Potter, C.C., Foltinek, D.S., 1997. Formation elastic parameters by deriving S wave velocity logs. *CREWES Research Report 1997*, Vol. 9, 1-13.**
- **Yilmaz, Özdogan, 1987. Seismic data processing. *Society of Exploration Geophysicists* 1987.**
- **Gadallah, Mamdouh R., Fisher, Ray L., 2005. Applied Seismology: a comprehensive guide to seismic theory and application. *Penn Well Corporation*, 1st American ed. 2005.**
- **Fagin, Stuart W., 1991. Seismic Modeling of Geologic Structures. *Geophysical Development Series*, vol. 2, 3-43.**